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EVALUATION OF MALATHION, SYNERGIZED PYRETHRUM, AND DIATOMACEOUS EARTH ON SHELLED CORN AS PROTECTANTS AGAINST INSECTS . . . IN SMALL BINS

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PREFACE

This report presents results of one of four closely related studies concerning small-bin, intermediate-type experiments with grain treated with insecticidal materials. The first report, "Evaluation of Malathion, Synergized Pyrethrum, and Diatomaceous Earth as Wheat Protectants . . . In Small Bins," Marketing Research Report No. 726, was published in August 1965. Another report will compare the effectiveness of different dosage levels of two diatomaceous earths and two silica aerogels with the standard malathion application in protecting wheat. A fourth report, on protective treatments of grain sorghum, will be published later.

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The studies were conducted at the Manhattan, Kans., station of the Stored-Product Insects Research Branch, Market Quality Research Division, Agricultural Research Service, U. S. Department of Agriculture. J. L. Wilson, Ralph L. Ernst, Warren E. Blodgett, and Leon Hendricks assisted in conducting the entomological phases of the work. The Chemical Unit at the Stored-Product Insects Research and Development Laboratory at Savannah, Ga., made all of the residue determinations.

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USE PESTICIDES SAFELY

If you use pesticides, apply them only when needed and handle them with care. Follow the directions and heed all precautions on the container label. If pesticides are handled or applied improperly, or if unused portions are disposed of improperly, they may be injurious to humans, domestic animals, desirable plants, honey bees, and other pollinating insects, fish, and wildlife, and may contaminate water supplies.

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Evaluation of Malathion, Synergized Pyrethrum, and Diatomaceous Earth on Shelled Corn as Protectants Against Insects . . . in Small Bins

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SUMMARY

Malathion at two dosage rates, pyrethrum synergized with piperonyl butoxide, and a diatomaceous earth were applied to uncleaned shelled corn as protectants against insect attack in small bins.

Damaging infestations of mixed populations of insects became firmly established during the 12 months of storage in all bins of untreated corn and corn treated with the diatomaceous earth at the rate of 125 pounds per 1,000 bushels. Corn protected by the diatomaceous earth had less damage than untreated corn.

The 1.5-pint per 1,000-bushel dosage of malathion emulsifiable concentrate afforded nearly complete protection from insect damage for 12 months, and the 1.0-pint dosage of malathion and the 1.0-quart dosage of synergized pyrethrum were only slightly less effective. A marked decrease occurred in the malathion residues during the first month of storage; after that, the decrease was gradual.

The synergized pyrethrum maintained a high degree of repellency throughout the storage period. The piperonyl butoxide residues degraded more or less gradually during the first 6 months to a stabilized level, which was maintained throughout the last 6 months of storage.

A small amount of diatomaceous earth which did not cling to the kernels fell free of the corn during the filling of the bins. This inert material reduced the test weight of the corn about 3.5 pounds per bushel.

BACKGROUND AND OBJECTIVES

The primary objective of this study was to compare the effectiveness of malathion and synergized pyrethrum emulsions and a diatomaceous earth (inert dust) as protectants of shelled corn against insect attack.

In general, three phases of testing are required to develop a protective treatment for grain; namely, (1) a preliminary laboratory evaluation of candidate insecticidal materials, (2) an intermediate, small-bin evaluation, and (3) full-scale bin, elevator, and warehouse tests. The most promising candidate materials are selected from the preliminary laboratory studies, and the dosage rates and residue degradation are explored in intermediate, small-bin tests. Five-cubic-foot cylindrical masonite bins have been successfully used in extensive intermediate-type storage studies with corn,[1] farmers stock peanuts,[2] and wheat.[3] Only the

[1] La Hue, D. W., Herbert Womack, and B. W. Clements, Jr. treatments for the protection of stored southern-grown corn from rice weevil attack—exploratory tests. U.S. Dept. Agr. Mktg. Res. Rpt. 272, 20 pp., illus. 1958.

[2] La Hue, D. W., B. W. Clements, Jr., and Herbert Womack. in-storage treatments for the protection of farmers stock peanuts from insect damage—exploratory tests. U.S. Dept. Agr. Mktg. Res. Rpt. 363, 32 pp., illus. 1959.

[3] La Hue, D. W. evaluation of malathion, synergized pyrethrum, and diatomaceous earth as wheat protectants. . . . in small bins. U.S. Dept. Agr. Mktg. Res. Rpt. 726, 13 pp., illus. 1965.

materials and dosages that demonstrate effective possibilities in the small-bin tests are field tested on a large scale. Considerable money and time are saved by early elimination of ineffective materials and procedures from the experiments.

In this test, two dosage levels of malathion and single dosages of a synergized pyrethrum and a diatomaceous earth were tested, using the small-bin method intermediate between the laboratory-type, small-jar tests and the full-scale field applications.

MATERIALS AND METHODS

The experiment was conducted from January 1961 to July 1962. Uncleaned and untreated shelled yellow corn, purchased locally at harvest, was stored in an unheated barn for 1 month before use.

Emulsion sprays prepared from premium-grade 57-percent malathion emulsifiable concentrate were applied to 20-bushel lots of corn at dosages of 1.0 and 1.5 pints per 1,000 bushels. A piperonyl butoxide-pyrethrum emulsifiable concentrate (Pyrenone® 60-6 O.T.) was used on 20-bushel lots at a dosage of 1.0 quart per 1,000 bushels. Neutral distilled water was used in formulating the sprays for application in a Mist-O-Matic Seed Treater, adjusted to apply 5 gallons of finished spray per 1,000 bushels of corn. An excess of spray material was prepared to allow for proper agitation and application.

The diatomaceous earth (Perma-Guard®) was applied at the rate of 125 pounds per 1,000 bushels to 2-bushel lots. The earth and corn were thoroughly mixed by rotating them in a barrel roller for 5 minutes.

Immediately after treatment, about 4 bushels of the treated grain was placed in each of the 5-cubic-foot bins. The bins were made by rolling a 2- by 6-foot sheet of ⅛-inch untempered masonite into a cylinder, smooth side inside, and fastening the 4-inch overlapping edges with short, round-headed stove bolts. The cylinders were placed upright on a 2-foot-square piece of building felt over masonite. The tops were left open. Five replications of each treatment, with 5 check bins, were placed in a 5 by 5 block arrangement in a 13- by 16-foot room on the second floor of a heated dwelling house.

The temperature in the storage or infestation room ranged from 53° to 94° F. during the winter and from 73° to 95° during the summer months. The humidity, which was not controlled, varied greatly during the storage period. It was exceptionally low during cold winter periods, ranging from 13 to 49 percent when the forced-air-circulating, gas-fired furnace was in full operation, but ranged from 32 to 98 percent during the spring, summer, and fall months, with minimum and maximum averages of 45.6 and 79.7 percent, respectively.

Rice weevils (*Sitophilus oryzae* (L.)), confused flour beetles (*Tribolium confusum* (Jacquelin duVal)), red flour beetles (*T. castaneum* (Herbst.)), flat grain beetles (*Cryptolestes pusillus* (Schönherr)), and saw-toothed grain beetles (*Oryzaephilus surinamensis* (L.)), were released as mixed lots of about 6,000 insects each in the infestation room in the aisles and around the bins. These lots were released 12, 42, 115, 195, and 286 days after the experiment began. Smaller lots were released during the first, fourth, fifth, sixth, seventh, and eighth months.

SAMPLING

Replicated 1-gallon samples of each treatment were taken as the treated grain fell from the seed treater. Other 1-gallon samples were taken from each bin as the surfaces were leveled. These two lots of samples were left undisturbed in open 1-gallon, large-mouthed glass jars in the storage room and exposed to a continuous infestation by the mixed populations of insects. Other composite samples taken at the same time were used in the determinations of the moisture content, weight per bushel, and chemical residues.

After 1, 3, 6, 9, and 12 months of storage, samples of corn were taken from the bins with a nonpartitioned grain trier or probe. The probe was inserted vertically, twice near the center and about 2 inches from the bin wall in each of the four quadrants. The insects were screened out with a gravity screen, and the live insects were counted for an estimation of the populations in the various bins. The fine dust from samples containing the diatomaceous earth was immediately separated from the screenings with an 18-mesh sieve and was returned to the probe sample and mixed for 15 minutes with a wheel mixer.

Replicated 125-gram subsamples of the probe samples were placed in ½-pint covered cardboard cartons for toxicity tests with adult rice weevils and confused flour beetles. Other replicated 125-gram subsamples from all bins of each treatment were placed in food preference or selection chambers to determine the repellency or attractiveness of the treated corn in the different bins when the insects had a choice of all treatments.[4] Later, after the bioassay and food preference tests had been completed and all adult insects had been removed, the subsample replicates from each bin were combined and stored in screen-covered 1-quart glass jars to provide an estimate of damage by the progeny of the insects involved.

The remainder of the corn from the probe samples was briefly sealed in 1-gallon jars until used for determining moisture content and test weight, and preparing samples for residue analyses.

Following the major introductions of insects in the storage room, observations were made to see which bins they entered. Observations were also made, from time to time, of the numbers of free-crawling insects in the different areas of the storage room. The appearance of weevil frass and dusts around the base of each bin was recorded as an indication of general insect activity in that bin.

During the termination of the 12-month study, as the individual bins were emptied, two 1-gallon samples were progressively collected from top to bottom. These samples were screened with an 8-mesh gravity screen to remove the insects, kernel bits, and insect frass. The corn was retained in covered jars for 60 days for a record of progeny emergence. The screenings were sifted over a No. 18 sieve to separate the insect frass and other dusts from the insects and kernel bits. The frass and other dusts were weighed for an estimation of the extent of insect damage to the corn.

Five replicated, 100-kernel samples from each bin were examined to determine the percent of kernels damaged by insects and the kernel weight loss due to insect feeding during 12 months' storage.

RESULTS

Moisture Content

Marked reductions occurred in the moisture content of the corn the first 3 months of storage (table 1). During that time, the relative humidity averaged about 29.0 percent, with a minimum of 13 percent. Minimum and maximum daily averages were 21.4 and 36.5 percent, respectively. Although the relative humidity was higher during the next 6-month period, with minimum and maximum averages of 45.6 and 79.7 percent, respectively, the moisture content of the corn increased only about 1.0 percent. The moisture content remained nearly constant or decreased slightly during the last 3 months of storage.

Insecticide Residues

The residues recovered by chemical analysis from the different bins at each examination were fairly uniform throughout the storage period. Values are expressed in parts per million (p.p.m.) of the insecticide, based on the actual weight of the corn. Initial residue recoveries of 3.96 and 7.86 p.p.m., respectively, from the 1.0- and 1.5-pint applications of malathion were much lower than expected. The greatest loss of residues occurred during the

[4] See footnote 3.

TABLE 1.—*Moisture content of corn at given intervals after insecticide treatment*

Insecticide and dosage per 1,000 bushels	Moisture content—						
	Before treatment	Immediately after treatment	After 1 month	After 3 months	After 6 months	After 9 months	After 12 months
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Malathion:							
1.0 pint	13.47	13.57	11.13	9.75	10.85	10.71	10.16
1.5 pints	13.50	13.40	10.96	9.70	10.71	10.63	10.01
Synergized pyrethrum:							
1.0 quart	13.50	13.68	11.22	10.03	10.95	10.82	10.35
Diatomaceous earth:							
125 pounds	13.40	12.99	10.50	9.39	10.33	10.23	10.31
None	13.42	13.37	11.04	9.93	11.07	10.87	10.88

first month of storage; after that the malathion residues gradually decreased (table 2).

The initial average residue recovery of piperonyl butoxide was 12.32 p.p.m., which was lower than expected. However, the residue degraded in an acceptable and uniform pattern for the first 6 months, apparently reaching a level of stability at that time. It is assumed that the recovery of the piperonyl butoxide can be used to estimate the pyrethrins residues at a 10 to 1 ratio, the proportion in the base emulsifiable concentrate.

Insect Populations

Insects moved freely and uniformly throughout the different areas of the infestation room. Nearly twice as many insects were counted on the floor as on either the walls or ceiling. The numbers of insects seen entering the bins of corn, during 30-minute observation periods within 4 hours after major introductions of mixed populations into the infestation room, indicated that the insects avoided corn treated with synergized pyrethrum and with diatomaceous earth (table 3). Insects entered the malathion-treated and untreated check bins readily.

The numbers of live adult insects, predominantly rice weevils and flour beetles, that were recovered in the probe samples at specified intervals indicated the populations within the bins throughout the storage period (table 4). After 3 months, many more insects were found in the untreated check bins than in the corn treated with the diatomaceous earth. Comparatively large numbers were recovered from the untreated check corn and the corn treated with the diatomaceous earth in all subsequent sam-

TABLE 2.—*Residues on shelled corn at given intervals after insecticide treatment*

Insecticide and dosage per 1,000 bushels	Calculated application	Residues recovered by chemical analysis—					
		Immediately after treatment	After 1 month	After 3 months	After 6 months	After 9 months	After 12 months
	P.p.m.	*P.p.m.*	*P.p.m.*	*P.p.m.*	*P.p.m.*	*P.p.m.*	*P.p.m.*
Malathion:							
1.0 pint	11.72	3.96	1.16	1.52	1.16	0.60	0.62
1.5 pints	17.58	7.86	3.84	3.38	2.28	1.66	1.40
Synergized pyrethrum: [1]							
1.0 quart	27.52	12.32	10.24	7.72	5.68	5.00	6.12

[1] Analyses were made for piperonyl butoxide, and it is assumed that the recoveries can be used to estimate the residues of pyrethrins at a 10 to 1 ratio.

TABLE 3.—*Insects entering bins of corn during 30-minute observation periods following major insect releases in infestation room at given intervals after insecticide treatment*

Insecticide and dosage per 1,000 bushels	Insects entering corn during observation periods after interval of—			
	42 days	116 days	196 days	288 days
	Percent	*Percent*	*Percent*	*Percent*
Malathion:				
1.0 pint	26.3	25.3	27.7	37.0
1.5 pint	43.3	35.5	31.5	22.4
Synergized pyrethrum:				
1.0 quart	1.3	4.4	4.2	4.6
Diatomaceous earth:				
125 pounds	2.6	5.8	3.6	9.9
Untreated check	26.5	29.0	33.0	26.1
Total observed	100.0	100.0	100.0	100.0
	Number	*Number*	*Number*	*Number*
Total observed	1,401	1,606	1,854	1,855

plings. Only a few live insects were found in the samples from either malathion or synergized pyrethrum treatments during the entire storage period.

The insect excrement and the fine dust appearing around the bases of the bins varied according to the insect populations within the bins. No dust or excrement appeared at any time around the bases of bins containing corn treated with the 1.5-pint dosage of malathion. Traces or small amounts were found around the bins containing corn treated with the synergized pyrethrum, and even less around bins with the 1.0-pint dosage of malathion. Medium to heavy deposits were around all bins of corn treated with the diatomaceous earth, attesting to the large populations of insects within these bins during the latter part of the storage period. Large amounts of dust were found around all bins of untreated check corn by the eighth month.

TABLE 4.—*Live adult insects in all probe samples of insecticide-treated corn taken during the 12-month storage period*

Insecticide and dosage per 1,000 bushels	Insects in samples taken after—				
	1 month	3 months	6 months	9 months	12 months
	Number	*Number*	*Number*	*Number*	*Number*
Malathion:					
1.0 pint	0	17	26	15	12
1.5 pints	0	5	6	13	2
Synergized pyrethrum:					
1.0 quart	2	7	43	36	22
Diatomaceous earth:					
125 pounds	22	60	573	531	170
Untreated check	80	425	573	428	269

Food Selection Studies

The unequal numbers of insects seen entering the bins containing corn treated with the different insecticidal materials during the first part of the storage study (table 3) suggested a need for multichoice food preference or selection studies. The avoidance by rice weevils of corn treated with the synergized pyrethrum was confirmed in tests made 6, 9, and 12 months after treatment (table 5). These results also support the findings in table 2, which suggest a stability level of piperonyl butoxide residue after 6 months' storage.

In these tests, the rice weevils did not avoid the corn treated with the diatomaceous earth—

TABLE 5.—*Food selection by rice weevils among corn samples taken 6, 9, and 12 months after insecticide treatment*

Insecticide and dosage per 1,000 bushels	Weevils that entered corn samples after a storage period of—		
	6 months	9 months	12 months
	Percent	*Percent*	*Percent*
Malathion:			
1.0 pint	19.58	22.27	25.99
1.5 pints	23.37	21.89	25.73
Synergized pyrethrum:			
1.0 quart	4.21	2.89	5.77
Diatomaceous earth:			
125 pounds	25.43	27.34	16.02
Untreated check	27.41	25.60	26.49

a direct contrast to the observations made in the infestation room. Part of the diatomaceous earth dust originally clinging to the kernels of corn was lost in the clouds of dust formed during the sifting of the probe samples to remove the insects. The dust had not adhered well to the kernels during treatment, and some of it fell free into the bins during the filling. It is logical to assume that there was a mass effect from the dust in the bins, but that this was lost during the handling of the individual samples withdrawn by probing. It was also observed that greater amounts of dust were recovered during probing from the bottom part of the bin and that the insect populations in the corn treated with the diatomaceous earth were in only the upper part of the bins.

Malathion-treated corn neither repelled nor attracted the rice weevils.

Toxicity Studies

Mortality readings were made 7 and 14 days after the 125-gram subsamples had been infested with about 25 rice weevils or flour beetles. Both dosages of malathion were completely effective against the rice weevil for 9 months (table 6). Mortality from the 1.0-pint application was not satisfactory in tests conducted 12 months after treatment, but the 1.5-pint dosage was still effective.

The synergized pyrethrum killed 100 percent of the rice weevils during the 1- and 3-month exposures, but its effectiveness against this insect declined slightly thereafter.

The diatomaceous earth killed only 83.8 percent of the rice weevils exposed 14 days, 1 month after treatment. Very little killing action was noted in subsequent tests.

The numbers of confused flour beetles killed after a 14-day exposure by both dosages of malathion and by synergized pyrethrum during the 1- and 3-month tests were acceptable. The effectiveness of these treatments against this insect declined rapidly directly after that (table 7).

The diatomaceous earth did not kill the confused flour beetles in any of the exposures.

TABLE 6.—*RICE WEEVIL ADULTS: Mortality after exposures of 7 and 14 days to samples of insecticide-treated shelled corn*

Exposure period, insecticide, and dosage per 1,000 bushels	Mortality of insects released in corn after a storage period of—[1]				
	1 month	3 months	6 months	9 months	12 months
	Percent	*Percent*	*Percent*	*Percent*	*Percent*
7 days:					
Malathion:					
1.0 pint	100.0	100.0	100.0	----	24.6
1.5 pints	100.0	100.0	99.8	----	93.8
Synergized pyrethrum:					
1.0 quart	100.0	100.0	90.2	----	51.5
Diatomaceous earth:					
125 pounds	39.7	6.6	15.5	----	6.9
Untreated check	2.6	.6	6.3	----	2.2
14 days:					
Malathion:					
1.0 pint	100.0	100.0	100.0	99.2	47.6
1.5 pints	100.0	100.0	100.0	100.0	99.1
Synergized pyrethrum:					
1.0 quart	100.0	100.0	91.0	78.2	87.5
Diatomaceous earth:					
125 pounds	83.8	17.0	21.5	8.6	29.2
Untreated check	5.7	1.4	8.4	6.2	8.2

[1] Mortality readings not made on samples exposed for 7 days after 9 months' storage.

TABLE 7.—*CONFUSED FLOUR BEETLE ADULTS: Mortality after exposures of 7 and 14 days to samples of insecticide-treated shelled corn*

Exposure period, insecticide, and dosage per 1,000 bushels	Mortality of insects released in corn after storage period of—			
	1 month	3 months	6 months	12 months
	Percent	*Percent*	*Percent*	*Percent*
7 days:				
Malathion:				
1.0 pint	89.4	24.2	11.1	3.9
1.5 pints	100.0	56.5	24.5	10.5
Synergized pyrethrum:				
1.0 quart	60.2	2.1	4.2	1.5
Diatomaceous earth:				
125 pounds	5.6	1.6	.8	1.1
Untreated check	0.4	1.5	1.6	.5
14 days:				
Malathion:				
1.0 pint	92.5	73.1	13.1	7.4
1.5 pints	100.0	84.4	28.6	15.2
Synergized pyrethrum:				
1.0 quart	84.3	97.3	8.4	4.2
Diatomaceous earth:				
125 pounds	11.9	3.2	1.9	2.4
Untreated check	.8	2.7	2.0	1.9

Insect Emergence

Corn samples taken progressively as the bins were emptied during the termination of the storage study were held for 60 days to record how many insects emerged from inside the kernels. These samples had been continuously exposed to insects for the 12-month storage period. All free-moving insects, kernel bits, and frass had been screened out. Only two insects emerged from the samples of corn from the 1.0-pint and four from the 1.5-pint malathion treatments, and 42 insects emerged from the samples from the synergized pyrethrum treatment (table 8).

A considerable number of insects emerged from the corn treated with the diatomaceous earth; however, four times as many emerged from the untreated corn. It was ascertained that a few flour beetle larvae remained in the rice weevil tunnels during the screening.

Insect Damage

The extent of insect damage to the shelled corn in storage depends largely on the amount of residues remaining on the grain and the number and species of insects present. An insect may inflict a certain amount of discernible damage to the kernels before it is killed by chemical residues or other means. Damage to the inside of the kernels results in a loss of weight. If heavily damaged inside, the kernels may break into fragments during handling. All such types of damage were observed in this test.

The amount of insect damage to the shelled corn in this test was estimated by various methods, such as the amount of visible damage to undisturbed jar samples taken at the beginning of the storage period, the amount of insect frass and other dust recovered from terminal samples, the loss in test weight in pounds per

TABLE 8.—*Emergence of live adult insects from 1-gallon samples of insecticide-treated corn taken at the end of the experiment*

Insecticide and dosage per 1,000 bushels	Rice weevils	Flour beetles	Flat grain beetles	Others	Total
	Number	*Number*	*Number*	*Number*	*Number*
Malathion:					
1.0 pint	0	2	0	0	2
1.5 pints	0	2	0	2	4
Synergized pyrethrum:					
1.0 quart	4	14	12	12	42
Diatomaceous earth:					
125 pounds	223	155	7	87	472
Untreated check	808	265	498	107	1,678

TABLE 9.—*Visible damage observed after given intervals in undisturbed 1-gallon jar samples of shelled corn collected immediately after insecticide treatment and subjected to mixed populations of insects*

Insecticide and dosage per 1,000 bushels	Insect damage observed after a storage period of—[1]				
	3 months	6 months	9 months	12 months	15 months
	Rating	*Rating*	*Rating*	*Rating*	*Rating*
Malathion:					
1.0 pint	0	0	0	0	1.2
1.5 pints	0	0	0	0	0
Synergized pyrethrum:					
1.0 quart	0	0	0	.4	1.4
Diatomaceous earth:					
125 pounds	0	.8	1.6	3.2	[2] 5.0
Untreated check	0	2.2	3.2	4.4	[3] 5.0

[1] Damage rating code: 0 = no visible infestation or damage; 1 = slight damage as evidenced by a few insects and a small amount of frass; 2, 3, 4 = ascending numbers of insects and corresponding amount of insect frass; 5 = large infestation with great amounts of insect frass and spoilage of grain.

[2] Three spoiled samples discarded before the 15-month reading.

[3] Five spoiled samples discarded before the 15-month reading.

bushel, the percent of kernels that had insect damage, and a calculation of kernel weight losses.

Rankings of the treatments for their effectiveness in the prevention of insect damage were consistent. The 1.5-pint dosage of malathion was strikingly effective. The applications of 1.0 pint of malathion and of the synergized pyrethrum gave comparable and satisfactory protection. The diatomaceous earth provided some protection in comparison with the heavy damage to the untreated corn.

During the 15-month exposure to insects, no infestations were established in the 1-gallon samples of corn taken immediately after treatment with the 1.5-pint dosage of malathion (table 9). Corn treated with the 1.0-pint dosage of malathion and the synergized pyrethrum became infested during the latter part of the observation period and sustained some damage. Insect infestations continued to develop in the untreated corn and in the corn treated with the diatomaceous earth, until the corn was spoiled.

Damage to samples of corn taken from the bins during the leveling procedures, although slightly greater, paralleled the damage to samples taken immediately after treatment.

The amount of damage inflicted by the insects during storage was apparent from the weight of dust and insect frass in samples progressively collected as the bins were emptied (table 10). Damage to corn treated with the 1.5-pint dosage of malathion was minor. Equal but relatively small amounts of dust were recovered from corn treated with the 1.0-pint dosage of malathion and the synergized pyrethrum. The large amounts of dust recovered from corn treated with the diatomaceous earth show that this corn sustained heavy damage.

TABLE 10.—*Weight of dust and insect frass from insecticide-treated corn samples collected as bins were emptied*

Insecticide and dosage per 1,000 bushels	Dust and frass weight	
	Average	Range
	Grams	*Grams*
Malathion:		
1.0 pint	3.1	1.2– 6.5
1.5 pints	1.3	.4– 2.4
Synergized pyrethrum:		
1.0 quart	3.4	1.1– 8.0
Diatomaceous earth:		
125 pounds	88.4	70.2–111.8
Untreated check	122.2	95.3–203.3

TABLE 11.—*Test weights per bushel and loss or gain in weight of insecticide-treated corn at given intervals during storage*

Insecticide and dosage per 1,000 bushels	Weight per bushel—						Loss (−) or gain (+)
	Before treatment	Immediately after treatment	After 3 months	After 6 months	After 9 months	After 12 months	
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Malathion:							
1.0 pint	58.0	57.7	58.4	58.8	58.4	58.4	+0.4
1.5 pints	58.0	58.0	58.2	58.4	58.1	58.7	+ .7
Synergized pyrethrum:							
1.0 quart	57.9	57.8	58.1	58.6	58.2	57.7	− .2
Diatomaceous earth:							
125 pounds	58.1	54.5	54.6	54.9	53.9	51.2	−6.9
Untreated check	58.2	58.4	57.4	57.0	56.1	46.6	−11.6

When the diatomaceous earth was applied, it caused an immediate weight loss of 3.6 pounds per bushel of corn (table 11). The adherence of the dust to the corn affected the flowability and the settling and nestling qualities of the grain. This resulted in a smaller number of kernels per given volume, and thus reduced the weight per bushel. The additional weight loss of 3.3 pounds per bushel in the 12 months after treatment was not as great as was expected from the large amounts of insect frass recovered from the terminal samples (table 10) and from the visible insect damage to samples retained in jars (table 9). As the dust was gradually removed from the kernels by handling, the corn may have settled more solidly and thus recovered some of the initial weight loss per bushel.

No significant losses in test weight due to insect damage occurred to corn treated with either dosage of malathion and with synergized pyrethrum. The untreated corn lost about 20 percent of its test weight from insect damage during the 12 months.

During the termination of the 12-month storage study, the percent of insect-damaged kernels and the calculated kernel weight loss was determined from composited sample lots of 500 kernels from each bin. Insects attacking the corn treated with the 1.5- and 1.0-pint applications of malathion and with synergized pyrethrum evidently inflicted substantial damage before being killed by the residues, as 5.04, 13.80, and 17.40 percent of the kernels, respectively, were infested or damaged during the storage period (table 12).

The diatomaceous earth did protect the corn somewhat, compared with the untreated corn, but 42.16 percent of the kernels were attacked and lost 17.33 percent of their weight.

The observations of visible damage by insect progeny to composites of subsamples that had been exposed to insects in the toxicity tests completely substantiated the findings of other parts of this study. Table 13 shows ratings of the visible damage by infestations that developed in the composite subsamples 6 months after the periodic samplings. A small amount of damage occurred in the 9- and 12-month composites from the 1.5-pint application of

TABLE 12.—*Kernel damage and calculated weight loss in insecticide-treated corn after 12-months' storage*

Insecticide and dosage per 1,000 bushels	Kernels damaged	Weight loss
	Percent	*Percent*
Malathion:		
1.0 pint	13.80	7.74
1.5 pints	5.04	5.78
Synergized pyrethrum:		
1.0 quart	17.40	9.43
Diatomaceous earth:		
125 pounds	42.16	17.33
Untreated check	89.52	30.59

TABLE 13.—*Visible damage by insect progeny in insecticide-treated corn samples collected at given intervals, composited into 1-quart subsamples after toxicity tests, and held 6 months before observation*

Insecticide and dosage per 1,000 bushels	Damage observed 6 months after a storage period of—[1]				
	1 month	3 months	6 months	9 months	12 months
	Rating	*Rating*	*Rating*	*Rating*	*Rating*
Malathion:					
1.0 pint	0	1.0	0.2	1.4	1.0
1.5 pints	0	0	0	1.2	.2
Synergized pyrethrum:					
1.0 quart	0	.6	1.2	2.4	1.8
Diatomaceous earth:					
125 pounds	1.4	4.0	3.4	4.8	2.8
Untreated check	3.6	4.4	5.0	5.0	4.2

[1] Damage rating code: 0 = no visible infestation or damage; 1 = slight damage as evidenced by a few insects and a small amount of insect frass; 2, 3, and 4 = ascending numbers of insects and corresponding amount of insect frass; 5 = large infestation with great amounts of insect frass and spoilage of grain.

malathion. In these particular observations, malathion ranked first in effectiveness with the 1.5-pint dosage and second with the 1.0-pint dosage, and the synergized pyrethrum ranked third. The diatomaceous earth was by far the poorest of the treatments; all samples obtained 1 month after treatment had sustained substantial damage.

FINDINGS

Comparative studies were made of the protection provided by two dosage levels of malathion, and single dosage levels of a synergized pyrethrum and a diatomaceous earth, when applied to uncleaned shelled yellow corn. All bin lots were given equal opportunity for infestation by mixed populations of insects. The following conclusions were drawn from the results of the study:

(1) Malathion at the rate of 1.5 pints of 57-percent premium-grade emulsifiable concentrate per 1,000 bushels protected shelled corn almost completely from insect infestation while the corn was exposed for 12 months to heavy and continuous attacks by mixed populations of stored-grain insects.

(2) Malathion applied at the rate of 1.0 pint gave excellent protection, but was not as effective as the 1.5-pint application.

(3) Synergized pyrethrum gave protection about equal to that of the 1.0-pint application of malathion.

(4) The diatomaceous earth did not adequately protect shelled corn against insect attack. This material did not adhere well to the waxy coating of the corn.

(5) The diatomaceous earth reduced the test weight of the shelled corn about 3.5 pounds per bushel.

(6) Malathion residues were generally effective against rice weevils in toxicity tests throughout the 12 months, but their effectiveness against confused flour beetles lasted less than 6 months.

(7) Corn treated with synergized pyrethrum seemed highly repellent to rice weevils in food selection studies and to the free-moving insects in the infestation room.

(8) Free-moving insects in the infestation room appeared to avoid the bins of corn with the diatomaceous earth treatment; however, when samples were exposed to rice weevils in food selection chambers, repellency was not evident.

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